

Are STEM from Mars and SSH from Venus?

A comparison of research and transfer activities in the hard and soft disciplines

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1. INTRODUCTION

There is a remarkably settled consensus within the innovation community that science, technology, engineering and mathematics (STEM) research is far more usable than other kinds of research, notably social sciences, humanities and arts (SSHA), and therefore STEM research is far more socially valuable. This assumption, which is drawn from a very narrow, and particular reading of innovation, has nevertheless become accepted as a norm in a much wider set of policy communities outside the innovation policy. In seeking to justify their resources, higher education and research policy communities have referred to their innovation benefits, and argued that it is these innovation benefits that make their activities – the research they fund – useful to society. Therefore, there has been a general acceptance within policy communities that it is self-evident that STEM is more useful than SSHA research. As argued in a strategic policy document such as *Backing Australia's Ability*, intellectual capital that drives innovation and productivity growth derives from science, mathematics and information technologies (Bullen *et al.*, 2004).

Our paper starts from the position that this argument is at least questionable, because of the slippage of an assumption from one domain – innovation and technology policy – to another domain, science and higher education policy. At the same time, there is an urgency around this problem because of the increasing evidence that governments are starting to shift their scarce resources in a time of crisis to only those areas perceived as most immediately useful. Indeed, as argued by O'Neill (2011: v) "*some held that in straitened times all public funding should go to research in science, technology, engineering and medicine*". In this paper, we therefore want to explore whether there has been a policy failure caused by restricting the definition of useful research to what is taken up in firm innovation processes, which is highly biased towards STEM.

The assumption of the natural superiority of STEM over SSHA disciplines and "*the way in which arts and humanities people think about themselves in a world where STEM [...] seems to rule*" (Crossick, 2009: 12), has provoked a significant concern about the place of the latter in society. We therefore focus on whether there are differences between academics in SSHA and STEM disciplines in ways that might make their research more or less useful. If SSHA is less useful than STEM research, then we would expect that to be reflected in the practices of academics in that they would make their outputs less open to users, because it is less used. Our argument is that looking at behavioural practice provides an insight into whether academics – who are pressed for time and have to make their own choices about priorities – do indeed prioritise making their research available to outside users in equal measure. If SSHA and STEM academics behave in similar ways in making their research open, this would suggest that there is at least a *prima facie* case to answer that there are users for both STEM and SSHA research – even if the transactions within which that research is used are not always easily measured in SSHA. Indeed, SSHA are facing a measurability problem (Dassen and Benneworth, 2011), because of their less tangible and measurable outputs (Benneworth and Jongbloed, 2010) leading to difficulties in proving their impact on society and the usability of their outputs by non-academics.

Therefore, in this paper, we ask the question whether there has been a policy failure that contributes to the now widespread belief that STEM research is more useful than SSHA research. We hypothesise that if this was true, then STEM researchers would behave differently to SSHA researchers, in order to facilitate the use of that research by potential users. Similar behaviour likewise suggests similar numbers of users, and similar norms of usability between SSHA and STEM. That finding would therefore also suggest that rather than STEM being more useful than SSHA, it may simply be the case that STEM users are more visible and that STEM use is more easily captured in economic data. This paper therefore seeks to make an important contribution to an intractable innovation policy question with increasing practical urgency, and also to deeper scientific debates concerning knowledge exchange, usability and societal development.

The structure of the paper is as follows. In section 2 we identify some stylized facts regarding research conducted in the SSHA areas which might account for – from the theory – why this systematic disadvantage and bias afflicts social sciences, humanities and arts; and we formulate hypotheses which are suitable to experimental testing. In section 3 we present an overview of the data and methodology for this study and we set out the variables used to test the hypotheses and their descriptive statistics. On the basis of the results about differences presented in section 4, in section 5 we provide a discussion of them and offer some implications and suggestions for future research.

2. SOCIAL SCIENCES, HUMANITIES AND ARTS CONTEXT IN THE SCIENCE SYSTEM

2.1. THE PROBLEM OF SSHA AS ONE OF DIFFERENCE

The current situation of the social sciences, humanities and arts could be the reflection of the extended thought that research impact and economic development is associated exclusively with STEM disciplines, which are the ones leading innovation and socio-economic growth. Indeed, the focus on university-industry interactions and on research outputs that can be easily measured, managed and researched have marked the tendency of academics and policy-makers to centre their debates in the context of STEM disciplines. In this paper, we are concerned with the internalisation by key policy makers of a sense that non-STEM disciplines make less of a contribution to society in a broad sense than STEM disciplines.

Perhaps the greatest indicator of this issue can be seen at the European level, where the European Framework programme is becoming more explicitly oriented towards solving grand societal challenges, and yet at the same time, the research line of Social Sciences and Humanities research is being abandoned and (partly) reincorporated in terms of the additional understanding which social sciences and humanities research provides for understanding these challenges. Another indicator of the perceived problem is that there have been number of studies and reports (mainly in the UK, Dutch, German and Australian context) that have attempted to highlight the public value of these disciplines and to demonstrate their contributions to society. The message is clear, social sciences and humanities research is regarded by public research funders as not having of itself the potential to create social value, but its value is only realised through its coupling to technical disciplines, in a way that is not assumed to be true for these STEM disciplines.

In this context, academics from the area of SSHA are facing a period of uncertainty linked to the doubts about the visibility of the value of their research and their capacity to prove that it is economically worthy to fund their research. But this seems to be premised on a misunderstanding, what you might term the super luminary fallacy, that these softer disciplines are different, and intrinsically less useful than the STEM disciplines, that is that STEM research is made from something special that makes it always more useful than SSHA research.

A key issue here is the notion of difference, that STEM is different from SSHA, and this is something that can clearly be tested, to see if there is evidence that SSHA research ‘behaves’ differently to STEM research. In order to do this, we have reviewed a number of reports to classify the various kinds of claims that are made about how SSHA research differs from STEM research, and we have created a two-level hierarchy of difference claims. The full hierarchy is presented in Annex 1. In the following sections, we set out this classification as a basis for developing testable hypotheses relating to the fundamental question of:

“Is social science, humanities and arts research different to science, technology, engineering and mathematics research in ways that make it systematically less useful to society?”

It is important to state that what follows are not claimed by us to be true, rather it is our attempt to provide a comprehensive taxonomy of the various claims that are made by others around why SSHA is less socially useful than STEM, in the context of current debates about the increasing importance of research's societal impacts. Below we have briefly presented the stylized facts about differences identified for the SSHA and the emerging theoretical hypotheses to test (for a more detailed explanation see Olmos-Peñuela and Benneworth, 2012). Despite the stylized facts are referred to the differences of non-STEM areas, our theoretical hypotheses will be tested with a sample of social sciences and humanities (SSH) researchers that is why arts are excluded from our hypothesis formulation.

2.2. DIFFERENCES IN THE RESEARCH AND TRANSFER PRACTICES

The first group of claims made about the differences between SSHA and STEM is that SSHA disciplines are organised in ways that make them intrinsically less useful.

The lack of visibility of SSHA contribution

The first claim made about a difference is that there is a lack of visibility of these disciplines that has led to an under-utilisation of their research. SSHA disciplines are seen as being too far from their eventual users which can be due to a lack of visibility of their research output. This mismatch between the SSHA research and its poor academic uptake could come from a problem on the supply side, that is, on the internal nature of the knowledge produced in these areas. As the distinction between basic and applied research (OECD, 2002) is perceived by some authors as very simplistic and overemphasised, we consider the Stokes's Quadrants (1997)¹ to better reflects the interplay in research activity between the pursuit of fundamental understanding and considerations of use (Abreu *et al.*, 2010; Hughes *et al.*, 2011). Hughes *et al.*, (2011) find that academics from arts and humanities describe their research as basic, with a higher orientation to the pursuit of fundamental understanding (Bohr Quadrant) compared to the rest of the areas. We propose a hypothesis about differences in the research orientation between STEM and SSH; and the we expect that STEM researchers to be more concerned with considerations of use and relevance (Edison Quadrant, Pasteur Quadrant), with results leading to a short time and visible impact in society and SSH researchers more oriented to basic and excellent research, less visible to non-academic users. According to this, we posit the following hypothesis:

Hypothesis 1. *SSH researchers are more concerned with the pursuit of fundamental understanding whereas STEM researchers are more focused on considerations of use.*

There is of course here a counter-claim, namely that this visibility problem can be regarded from the perspective that SSHA do not readily fit into to a simple technology transfer or knowledge transfer model constructed for STEM (Jaaniste, 2009; Bakhshi *et al.*, 2009; Hartley and Cunningham, 2001). The dominant model is focused on narrow indicators that only count for those formalized and transactional activities that can easily be measured, managed and researched. However, these institutionalized knowledge transfer activities (Geuna and Muscio, 2009) only represent a fraction of universities' full suite of interactions with and impacts upon society (D'Este and Patel 2007; Perkmann and Walsh 2007) and do not consider other forms of interactions such as informal collaborations. Tacit knowledge plays a more prominent role in SSHA than it does in STEM (AHRC, 2009: 15) hence, they are characterised by a lower codified research (Pilegaard *et al.*, 2010) and a

¹ Bohr Quadrant (pure basic research) represents research concerned solely with the pursuit of fundamental understanding; Edison Quadrant represents research solely interested in considerations of use (pure applied research) and Pasteur Quadrant represents the combination of both fundamental understanding and considerations of use (user-inspired basic research).

higher relevance of personal contacts between researchers and users (British Academy, 2008). Indeed, SSH is dominated by informal collaborations that do not leave an audit trail proving that knowledge exchange has taken place (Castro-Martínez *et al.*, 2011). Conversely, most of the research from STEM results on tangible products or technologies that require, in most of the cases, intellectual property protection which is in fact a temporary monopoly right to exploit the technology which need to be formalized. Therefore, in a context where the contribution of science is measured through narrow indicators that only count for those formalized and transactional activities, where SSH is dominated by informal collaborations and where STEM researchers are more likely to go one step further informal relationships by formalizing relationships through the channels of interactions institutionalized, we propose the following hypothesis:

Hypothesis 2. *SSH researchers use a higher proportion of informal pathways and a lower proportion of formal pathways to interact with non-academic actors compared to STEM researchers.*

Higher regional orientation of the SSHA (geographical scope)

The second claim made about the difference of SSHA as a disciplinary approach is that SSHA are far more particular and specific than STEM, the latter producing universal laws and explanations. In this sense, the claim is that SSHA activities are especially important at closer geographical levels (British Academy, 2004) and highly oriented towards regional or specific cultural communities. As noted by Edgar and Pattison (2006: 97-98): *“the humanities still speak to specific communities, unlike the natural sciences that at least aspire to speak to a universal humanity... [humanities] still appear to speak in the voice of particular communities and about issues that concern particular communities”*.

The research conducted in the area of SSHA is very often strongly context-oriented and cannot easily be extrapolated to other regions or communities. In a critical reading of Bate’s book (2010) *“The public value of the humanities”* (itself the result from the Impact Task Force created by the AHRC in 2008 to legitimate the investments in humanities and arts research), as we go through the book, we can identify a broad spectrum of research topic, each one often confined to a very specific research and specific audience –i.e. Deborah Howards and her research in the architecture of Venice and Veneto (Howard, 2011: 85) –. However, knowledge generated within STEM is seen to be used beyond a specific region or community and generating knowledge *“rooted in discovering increasingly and predictive universally applicable insights”* (Bakhshi *et al.*, 2008: 15). According to the above explained, we posit:

Hypothesis 3: *The frequency of involvement with national users related to international users is higher for SSH researchers than for STEM researchers.*

SSHA research for small audiences (scalability scope)

The third claim made about SSHA research is that individual pieces of research are used in a small and unimpressive way, for small audiences, leading to a limited scalability and lower levels of generalisability (Bakhshi *et al.*, 2008) compared to STEM research – i.e. exhibitions that are displayed in different museums of different countries, however, depending on the specificity of the topic, only a small audience might be interested on visiting it –. Here the claim is that SSHA is intrinsically less useful because there are fewer potential users for the research, which tends to have smaller impacts and audiences than for the STEM disciplines, the latter with a universalistic tendency (Bakhshi *et al.*, 2008) and a more global audience. Indeed, Hughes *et al.* (2011) find that arts and humanities researchers in the UK context reported more often that their research was no relevant for external organisations. Hence, SSH researchers feel that entities have little interest about their research as

only few non-academic entities can be interested in such specific researches; therefore we propose the following hypothesis:

Hypothesis 4. *STEM researchers feel more that there are few user organisations interested in their research than STEM researchers.*

Higher purpose of SSHA

The final claim for differences in the research practices is one that is often made by advocates and defenders of these soft disciplines: SSHA should not be judged on the limited bases of its contribution to society measured exclusively in economic terms. Unlike STEM disciplines, humanities have a higher purpose beyond the direct and visible application to economic growth, regarding scientific advance and the set-up of the basis enabling society to understand about generic and fundamental questions about the past, the present and the future, and about the ethical and cultural values that dominate and steer society decisions. For a more detailed understanding of the key functions of SSHA see the report *“That full complement of riches’: the contributions of the arts, humanities and social sciences to the nation’s wealth”* by The British Academy (2004) and Bigelow (1998) – (in Bullen *et al.*, 2004) – about the benefits provided by the research in humanities.

SSH researchers are *“opinion-makers and are called upon everyday media as experts”* (Stannage and Gare, 2001: 111) to address issues such the crisis, unemployment, immigration, and other social problems. Conversely, STEM research is not so directly linked to social current events or to the understanding of an on-going social phenomenon, but to singles discoveries leading to an occasional participation in diffusion activities to show their research output. According to this, we posit:

Hypothesis 5: *SSH researchers spend more time in diffusion activities than STEM researchers.*

2.3. DIFFERENCES IN THE RESEARCH IDENTITY

The second pair of claims is related to the fact that whilst SSHA and STEM might do similar kinds of things, the particularities of the differences between the fields mean that for various socially defined ways, they have a different value.

Misperception of the importance of business in receiving research

The first claim made for a symbolic difference between STEM and SSHA is because the former tends to work more with businesses and the latter more with public and voluntary sectors and because, in contemporary society, private enterprise has a privileged discursive position, likewise this means that for similar levels of activity, STEM is more socially useful than SSHA activity.

Indeed, as stated by Cassity and Ang (2006), humanities are generally removed from the interactions with the industry, as *industry* is a term usually associated to manufacturing and commerce. Of course this perception can be challenged in a society where physical output and technologies are not anymore the bases of innovation and economic growth, and new forms of innovation such as organizational innovation (OECD, 2005), where SSHA have much to contribute, are relevant for firms. In this sense, nowadays, research conducted in social science is tightly associated to the concepts of organizational learning, organisational management and human resources, which are essential in the current economy where knowledge (that resides in the individuals) and knowledge management are the bases to compete in the global market. Moreover humanities and arts play a relevant role in the cultural and creative industry (European Commission, 2010). Despite the above mentioned contribution of the SSHA to the economy, there is still a misperception of the importance of business in receiving research from SSHA and, in any case, that it is far comparable to the STEM contribution to firms. Hence, the hypothesis proposed is:

Hypothesis 6. *SSH researchers collaborate less with firms than STEM researchers.*

Divergence in the field and no simple message

One of the key problems is that different SSHA disciplines purport to be able to talk authoritatively about the same subject areas; however different fields can often have quite different ways of looking at the same subject area. Indeed, there is little unanimity in SSHA fields – the great example of this is economics, where depending on one’s theoretical perspective similar events can be interpreted in very different ways –, a very confusing message for policy makers, and clearly in contrast to the clear laws and universals believed to be revealed by STEM research. In this sense, as noted by Bakhshi *et al.* (2009: 110) “*The arts and humanities develop and re-evaluate earlier ideas and sources of evidence, viewing them from new perspectives and new contexts*”. The issue here is not that one is right and the other wrong, rather the point being that for the public, the STEM disciplines give hard answers to questions without this grey area for interpretation. This can be traduced in a reduction of public confidence in SSHA scientists because they are seen as one voice amongst many in a crowded global marketplace of ideas, and their opinions as equal to those of think-tanks or lobbyists, whilst STEM scientists have the advantage of being regarded as authoritative for the work they do.

Therefore the claim is that SSHA disciplines are able to talk less authoritatively about the world, and that reduces the value of the utility of the knowledge that they create because it is contingent and disputed rather than universal and established. Of course, a counter claim could be made that the subject domain for SSHA is more complex and therefore less knowable, and this diversity of approaches is necessary to ensure a detailed understanding of the issues and problems; but at the same time, it is clear there is still circulating a set of claims that SSHA is more akin to opinions, and therefore comparable with myriad opinions circulating in the public realm; and STEM research are more authoritative, but also rarer, and therefore more of a strategic asset thereby warranting public investment to ensure national access to these rare strategic assets. According to this, we would expect SSH researchers to feel a greater threat by trying to verify the validity of their research, considered less forceful and more uncertain than this get on the STEM area. Conversely, we would expect STEM researchers to be more interested in collaborating with external entities to check whether their research results are valid and can be applied beyond the academic sphere for the resolution of non-academic problems. Thus, we suggest the following hypothesis to be tested:

Hypothesis 7. *SSH researchers have less interest in checking the validity and applicability of their research than STEM researchers.*

2.4. DIFFERENCES IN THE RESEARCH USERS

The third pair of claims argues that SSHA and STEM collaborate with different type of users and that differences exist in later consumption of their research.

SSHA research users are mostly non-economic agents

A simple way of expressing this claim is the frequently evoked image of the humanities as an ivory tower, and that SSHA areas are seen as disconnected from the society. This thought promotes the assumption that there is no interaction between academics and non-academics in these disciplines, that is, no socio-economic contribution is done by soft disciplines. However, this assumption is made under the approach followed in technology transfer and knowledge transfer studies, which have mainly focused on university-industry relationships and have hardly considered a wider diversity of agents (Hughes *et al.*, 2011). Once the narrow utilitarian focus is abandoned, the evidences indicate that SSHA have connected to non-academics. Therefore, it is important to extend the range of

potential users of academic research to cover all the actual science-society interactions and to include non private economic agents such as public sector organisms and non-profit organisations.

Indeed, there are evidences that there is a high collaboration between SSHA researchers and a wide variety of entities such as industry – mainly creative industries – (Hughes *et al.*, 2011), public entities and the charitable sector (Castro-Martínez *et al.*, 2011; Gascoigne and Metcalfe, 2005; Hughes *et al.*, 2011). It should be noted that all this type of users are very different, also in their economic power, so the type of non academic agent can determine not only the research topic but also the academics level of commitment or their motivation to conduct their research. According to the studies reviewed, we posit:

Hypothesis 8. *The frequency of collaborations with non-economic agents relative to private sector is higher for SSH researchers than for STEM researchers.*

Invisibility of research to the user in the consumption process (lack of traceability)

This last claim is related to the difference in the way that the research is consumed by users. On the one hand, STEM research is much more economically visible to its users, who then act as vocal and enthusiastic advocates. On the other hand, SSHA proceeds on a mazy run towards the market, and by the end can be consumed in ways that leave the user completely unaware of the research that has gone into the product or activity.

First of all it is interesting to note that contributions to the industry sector are more visible for hard disciplines. Marketing department in companies permits to highly promote new research, and to advertise to future clients the benefits of the product they buy. These research results – most of them technological innovation applied to products that will be commercialized and advised by famous firms – are recognised by the future users as the new characteristics of these new products are often the reason of why the clients buy them and of it willingness to pay a determined amount of money. Thus, the invisibility of the SSHA research results when users are consuming it could be related to the fact that there are not high-tech SSHA companies who are continually reminding you that they are exploiting science to make your life better.

Users of SSHA results are not often aware of what they are consuming. The reason is that the type of research usually produced in these disciplines is not often commissioned by the final users as it often happens for STEM. One of the main users of STEM research is the industry. Firms are looking for a specific solution, a new product, a better process to reduce its production cost so they collaborate with the academia to reach a satisfactory solution to their problems. Firms, as clients and final users of STEM research, are aware of what they are paying for and of what they are consuming and how they are benefiting from this ad hoc research. However, this figure is not often reproduced in SSH, where the client is often an intermediary user of the research, but not the final user. Therefore, the lack of economic visibility of the consumption can be linked to the existence of intermediary research users (i.e. public sector), leading to a lower awareness of the SSH consumers because of the non direct contact with the final users. Conversely, we expect STEM research to be more linked to the final user that promotes the value of the research results. Thus, the hypothesis suggested is:

Hypothesis 9. *SSH researchers use less pathways that reach end users than STEM researchers and more pathways that reach intermediate users.*

The above presented theoretical hypotheses (summary in Annex 2) are tested through a number of variables that are defined in the following section. Before the variables description, some considerations about the database selection and the population characteristics are outlined.

3. DATA AND METHODOLOGY

3.1. DATABASE CONSIDERATIONS

A number of criteria have been used for the choice of the data source to test the hypotheses. Time and economic factors have been determinant to discard the option of elaborating an ad hoc database. Additionally, this is an exploratory study in which, from theoretical readings about the discussion around SSHA research, we propose a number of hypotheses that we want to evaluate. Thus, our main objective is not other than to explore the validity of our theoretical review through an experimental approach. For these reasons, we have chosen an existing database that meets a number of requirements: accessibility, richness of data, novelty (to be recent), and permitting the comparison between areas of knowledge, more specifically, between SSH and STEM disciplines.

In terms of choosing a suitable database, there are a number of studies which have generated material that would potentially be suitable for a study. The AHRC in the UK has been leading in terms of funding research into this area specific to arts and humanities research. Hughes *et al.* (2011) analysed their existing database which captured the behaviour and reported activities of more than 22,000 academics, 3,650 of those academics in the arts and humanities sectors along with a database of user reactions and interviews with key respondents. This and other databases provide an interesting source of material for comparative work with the eventual database chosen. In this paper, we are exploring a series of novel propositions which together add up to an experimental way of considering social sciences, humanities and arts research impact. The point of this is to explore whether our approach – attempting to develop hypotheses for social sciences, humanities and arts research’s impact theoretically and then to test them –, is a feasible way of proceeding. In practical terms this imposes the requirement of using a database that is readily accessible, and therefore we have chosen one to which we already have access because of the team’s involvement in its construction.

Our final choice has been a recent database elaborated by two institutes² from the Spanish National Research Council (CSIC) in the framework of the IMPACTO project, commissioned by the CSIC. The objective for the elaboration of this database has been to conduct an empirical study of the activities that CSIC carry out with agents from the socio-economic environment. Thus, data contains the perception of the researchers belonging to the CSIC and their scientific activities. All the CSIC scientific areas of knowledge have been covered (which is essential to test our hypotheses) and questions have addressed research characteristics and researchers’ collaborations with non-academic agents. We are aware about the limitation of using an existent database that can be partially incomplete for the aim of our study. Nevertheless, we think that from the existing database to which we have access, this one is the best option to test our hypotheses as it dates from 2011, it is very rich in data and it is accessible for us. More detailed information about the database and the methodology is presented below.

² INGENIO (Institute for Innovation and Knowledge Management) and IESA (Institute for Advanced Social Studies).

3.2. POPULATION AND DATA COLLECTION

The empirical study is focused on the CSIC, the largest public research organisation in Spain. In 2010, CSIC had 136 centres and institutions distributed throughout Spain³ (CSIC, 2011). CSIC is divided in eight main areas of knowledge⁴ and the staff is distributed according the following categories: civil servants, contracted personnel and research fellows, which are in turn scientific staff, technicians and administration.

The population of the study is centred in the CSIC scientific staff, more particularly, in the CSIC researchers with a doctoral degree and with the possibility to appear as principal investigators in agreements and contracts with other entities (civil servants⁵ or contracted). Data facilitated by the CSIC Human Resources Department identified, at 30th November 2010, a total of 4,240 researchers meeting these requirements. The type of sampling has been a proportional stratification by areas of knowledge and professional categories⁶.

Data has been gathered through an online questionnaire, followed by a second mailing when researchers do not answer and a final reinforce through a telephone call if the researcher had not yet replied. Data collection has been done between the 7th April 2011 until the 24th May 2011. The final sample is 1,583 researchers. Table 1 presents the population and sample distribution by area of knowledge for our study.

TABLE 1. Population and sample distribution.

	Population (N)	Population (%)	Sample (N)	Sample (%)
STEM	3,838	91	1,466	93
SSH	402	9	117	7
TOTAL	4,240	100	1,583	100

Source: adapted from the IMPACTO project

The questionnaire approach has been built on the bases of the literature review about the effect of public research. Specifically, the review for the questionnaire is based on conceptual frameworks analysing the role of public research in business R&D and innovation processes (Cohen *et al.*, 2002; Schartinger *et al.*, 2002), with a special emphasis on those studies that reflect different transfer mechanisms and their impacts (Cohen *et al.*, 2002). Moreover, empirical studies about researchers' interaction with non-academics have also been revised.

³ With the exception of the “Escuela Española de Historia y Arqueología” in Rome

⁴ Humanities and Social Sciences and seven scientific areas corresponding to STEM: Biology and Biomedicine; Food Science and Technology; Materials Science and Technology; Physical Science and Technologies; Chemical Science and Technology; Agricultural Sciences; Natural Resources.

⁵ Scientific civil servants can hold the categories of *tenured scientist*, *scientific researcher* and *research professor*. Teachers and professors from universities which are attached to CSIC have been included in the category of tenured scientist or research professor, respectively.

⁶ Contracted researchers are slightly under-represented in the data base.

3.3. VARIABLES AND TEST CONSIDERATIONS

To operationalize the hypotheses proposed, we use a number of variables constructed from the CSIC questionnaire. The descriptions of the variables are presented below and descriptive statistics are presented in Tables 2a, 2b and 2c.

[Area]: binary variable coded 0 if the researcher belongs to the STEM area and 1 if the researcher belongs to the SSH area.

[Stokes's Quadrants]: categorical variable coded 1 for Empty Quadrant; 2 for Edison Quadrant; 3 for Bohr Quadrant and 4 for 'Pasteur Quadrant. To select the quadrant we consider two dimensions: the extent to which academic's research is inspired by knowledge advancement and the extent to which academic's research is inspired by application of its results outside the academia.

[Informality]⁷ and [Formality]⁸: continuous variables that measure the proportion of informal and formal pathways, respectively, used by a researcher to collaborate with entities. It is computed as the ratio of informal pathways used relative to the total pathways used; and the ratio of formal pathways used relative to the total pathways used, respectively.

[National orientation]: continuous variable that measures the proportion of researcher's collaboration with national entities relative to their collaborations with international entities. It is results of a ratio between researcher's collaborations with firms located in Spain, public sector and non-profit organisations; and, his collaborations with firms located outside of Spain and international organisms.

[Interest of the research]: ordinal variable that measures the extent to which a researcher perceives that other entities have little interest about his research. It is measured by a 4-point likert scale ranging from 1 (not at all) to 4 (often).

[Diffusion time]: continuous variable that measures the % of time that the researcher spends in diffusion activities.

[Firms]: continuous variable that measures the frequency of researcher's collaborations with firms. We use a 4-point likert scale from 1 (never) to 4 (often).

[Check validity]: continuous variable that measures the degree of importance a researcher assigns to check the validity or practical application of the research he has developed. This variable is measured through a 4-point likert scale from 1 (not important) to 4 (very important).

[Public Sector] and [Non Profit Organisation]: continuous variables that measure the frequency of researcher's collaborations with public sector organisations and non profit organisation, respectively, relative to his collaborations with firms. They are measured as the ratio of the collaborations with public sector organisations by firms and the ratio of the collaborations with non profit organisations by firms, respectively. These variables are used to test the hypothesis related to the collaboration with non-economic agents.

[End users] and [Intermediate users]: ordinal variables that measure the variety of pathways through which a researcher collaborates with end users and intermediate users, respectively. By additively aggregating 14 binary variables corresponding to each different pathway used by a

⁷ *Informal* activities: Occasionally contacts or consultations; Technical services; Temporal stays; Training of postgraduates; Consultancy through committees and expert meetings; Participation in diffusion activities in professional environment.

⁸ *Formal* activities: Contract research; Research framed in a Spanish public program; Research framed in international programs; Courses and specialized training activities; Use of CSIC's infrastructures or equipments; License of patent; Creation of a new firm in partnership; Participation in the creation of a new centre or joint unit of R&D.

researcher to collaborate with the end users (firms) and the intermediate users (public sector organisations), we obtain these two variables taking integer values from 0 to 14.

TABLE 2. Descriptive statistics

Table 2a: Continuous variables	Range	Mean	S.D
Informality	0-1	0.57	0.177
Formality	0-1	0.43	0.177
National orientation	0-1	0.72	0.220
Diffusion time	0-100	4.09	6.693
Public Sector	0.25-4	1.18	0.710
Non Profit Organisation	0.25-4	0.84	0.518

Source: Own elaboration

Table 2b: Categorical variables	Distribution		
Area	7.5% (SSH)		
Stokes's Quadrants	(10.0%) Edison	(53.3%) Bohr	(22.1%) Pasteur

Source: Own elaboration

Table 2c: Ordinal variables	Range	Median	Highest distribution
Interest of the research	1 - 4	3	(32.7%) Some
Firms	1 - 4	2	(41.4%) 1-3 times
Check validity	1 - 4	3	(48.5%) Important
End users	0-14	2	(24%) 0 pathways
Intermediate users	0-14	4	(15%) 0 pathways

Source: Own elaboration

Most of the variables used to test the hypotheses are ordinal variables and continuous variables whose distribution does not match with a normal distribution. Therefore, according to these types of variables we use the Mann Whitney test (U) to statistically test whether there are differences in the sampling distribution of the different variables for SSH and STEM areas. For the categorical variable [Stokes's Quadrants] we use a Chi Square statistic to test whether there are significant differences between SSH researchers and STEM researchers in their distribution between the four categories proposed by Stokes (1997): Empty, Edison, Bohr and Pasteur.

4. EMPIRICAL RESULTS⁹

To empirically test the hypotheses formulated, we have applied Chi Square test (χ^2) or Mann Whitney test (U) to know whether there are statistical significant differences between SSH and STEM for the different variables proposed. Results are presented in Table 3. Null hypotheses for all the variables analyzed is that there are no differences between SSH and STEM. The null hypothesis is rejected if the *p-value* > 0.005.

The result of the χ^2 test corresponding to the Stokes's Quadrants indicates that we cannot reject the null hypothesis about differences in the research orientation (H1) as the *p-value* is 0.620. The theory suggest that SSH and STEM differs, the former being more oriented to fundamental understanding and the latter more concerned with the use and relevance of the research. However, we have not found evidence for that point, so we have to move towards rejecting the idea that SSH is different from STEM in terms of the research orientation.

For the rest of the variables we apply Mann Whitney test and we get the following results. We reject the null hypothesis about differences in the nature of the pathways used by researchers to collaborate with non-academic (H2) and we also reject the null hypothesis about the more regional or national orientation of SSH (H3), both with *p-value*=0.000. Our results support the theory which suggests that STEM researchers use more formalized activities than SSH researchers to collaborate, the latter using more informal mechanisms of interaction and being more involved with national entities.

For the variable [Interest of the research] measuring researchers' perception of the relevance (interest) of their research for user organisations, we cannot reject the null hypothesis (H4) as the *p-value* is 0.354. The theory predicts that SSH researchers have a greater feeling than STEM researchers about the lack of interest from non-academic entities about the research they are conducting; nevertheless, this is not supported by the evidence and we have to move towards rejecting this hypothesis. The result of testing H5 ([Diffusion time]) indicates that we can reject the null hypothesis (*p-values*=0.000) and that SSH researchers spend significantly more time in these type of activities related to STEM researchers. This result is in line with what the theory predicts.

To analyse the kind of differences in the research identity we tested the null hypotheses H6 ([Firms]) and H7 ([Check validity]). Our empirical result indicates that we can reject the null hypothesis H6 (*p-values*=0.000), that is, there are differences between SSH and STEM researchers in the extent to which they collaborate with firms. Theory predicts that there is a misperception of the importance of firms in receiving research from the SSH area which results in a little work of SSH researchers with firms in comparison with STEM researchers. This prediction is confirmed by our empirical results. For the hypothesis H7 we cannot reject the null hypothesis of differences between areas as we obtain a *p-value* = 0.571. The theory suggests that SSH researchers, as they conduct research regarded as few authoritative, are less interested than STEM researchers in checking the applicability of their research, however, our data do not support this assumption.

The first null hypothesis related to differences in users proposes that there are differences between areas in the collaborations with non-economic agents (H8). Mann Whitney results indicate that for the variables [Public Sector] and [Non Profit Organisation] we can reject the null hypotheses about

⁹ These results correspond to data from CSIC, where all disciplines are not equally represented due to historical and institutional reasons. The test presented have also been run with an evenly distribution of the scientific areas (by weighting data) to extrapolate the results and conclusions to other context, as our objective is to compare SSHA and STEM communities broadly (regardless of context). By this procedure, we obtain different results for one test run corresponding to the variable [Stokes's Quadrant] in which we find the following significant differences: Empty_{SSH}<Empty_{STEM}; Borh_{SSH}>Borh_{STEM}; Edison_{SSH}<Edison_{STEM}.

differences between areas ($p\text{-value}= 0.000$). The theory predicts that SSH researchers collaborate more with non-economic agents than STEM researchers, which is confirmed by our empirical data, which indicates higher mean values for SSH in both variables. The second null hypothesis related to differences in users proposes differences between areas in their diversity of interactions with end users and intermediate users. Results indicate that we can reject the null hypothesis H9 as we obtained $p\text{-value}<0.005$ for both variables [End users] and [Intermediate users]. We suggested that STEM are highly involved with end users whereas SSH are highly involved with intermediate users, which is confirmed by our empirical.

TABLE 3. χ^2 test result and Mann-Whitney test results

	Null Hypotheses tested with Mann Withney (U)	Differences between SSH and STEM	Mean ^a SSH	Mean ^a STEM
H1 ^b	[Stokes's Quadrants] _{SSH} = [Stokes's Quadrants] _{STEM}	SSH = STEM	–	–
H2	[Informality] _{SSH} = [Informality] _{STEM}	SSH > STEM***	0,62	0,56
	[Formality] _{SSH} = [Formality] _{STEM}	SSH < STEM***	0,38	0,44
H3	[National orientation] _{SSH} = [National orientation] _{STEM}	SSH > STEM***	0,77	0,72
H4	[Interest of the research] _{SSH} = [Interest of the research] _{STEM}	SSH = STEM	2,50	2,60
H5	[Diffusion_time] _{SSH} = [Diffusion_time] _{STEM}	SSH > STEM***	6,88	3,87
H6	[Firms] _{SSH} = [Firms] _{STEM}	SSH < STEM***	1,96	2,27
H7	[Check validity] _{SSH} = [Check validity] _{STEM}	SSH = STEM	3,09	3,12
H8	[Public Sector] _{SSH} = [Public Sector] _{STEM}	SSH > STEM***	1,71	1,17
	[Non Profit Organisation] _{SSH} = [Non Profit Organisation] _{STEM}	SSH > STEM***	1,38	0,81
H9	[End user] _{SSH} = [End user] _{STEM}	SSH < STEM***	1,50	2,69
	[Intermediate user] _{SSH} = [Intermediate user] _{STEM}	SSH > STEM***	4,90	4,09

Source: Own elaboration

*, **, and *** indicate that the coefficient is significant, respectively at the 10%, 5% and 1% thresholds.

^a Means are provided for ordinal variables for practical purposes. They indicate the direction of the differences between STEM and SSH.

^b H1 has been tested with a χ^2 test

5. CONCLUSIONS

The following section is mainly focused on the evidences found in our results about the differences between SSH and STEM areas and on whether there has been a policy failure in assuming that SSHA is less useful and therefore less valuable than STEM research because of the existing differences.

Our results do not indicate differences in the research orientation between areas¹⁰, however, when we focus on the nature of the collaborations results confirm that SSH researchers are significantly more engaged in informal pathways of interaction with non-academics whereas STEM researchers use more formalized pathways. This difference can be on the bases that SSH scientific results fall *under the radar* even if there is an actual knowledge flow between researchers and non-academics indicating that SSHA research is actually useful beyond the academic sphere. Indeed, as appointed in

¹⁰ This result should be taken with caution as we do not find consistent results when we test the hypothesis of the Pasteur Quadrant with weighted data allowing to have an evenly distribution of the disciplines.

most of the reports reviewed, SSHA make a vital contribution to society (AHRC, 2009; British Academy, 2008) however, they are under-recognised (Gascoigne and Metcalfe, 2005) and the research from these soft disciplines is not being exploited.

Results also suggest that there are no differences between researchers' perceptions about the degree of interest showed by other entities about their research. This result indicates that SSH researchers perceive the same interest from outside users than STEM researchers, therefore, their research is perceived as useful as STEM research even if the recipient can be different. Indeed, when we focus on the geographical position of non-academic users, we find that SSH researchers collaborate more with national entities and with non-economic entities whereas STEM researchers are more oriented to firms. As argued in the theoretical review private enterprise have a privileged discursive position so it is not surprising that SSH researchers 'collaborations with non-economic entities have not been considered at the same level than STEM researchers' interactions with firms. Additionally, the prevailing interest on university-industry studies has lead to a situation where SSH research go, to a certain extent, unnoticed in terms of usefulness in the limited science-industry scheme which does not necessary correspond to the actual situation.

From a point of view of the economic visibility of the consumption of the research outputs, results indicate that SSH researchers use more pathways to reach intermediate users than to reach end users. The visibility of the economic transaction that is generated when researchers collaborate directly with the end users diminished when there is an intermediary user involved in the process. Hence, the higher existence of intermediary users associated to the SSH area can be on the bases of a lower economic invisibility of their results, therefore, a less perception of the value of the activities that are conducted in this area.

As a summary of our findings, we can conclude that effectively, SSH and STEM are different in almost all the aspects we have analyzed. They have, in most aspects, different research and transfer practices, different research identity and different recipients or users of their research. However, these differences do not reflect that SSH are less useful or less valuable, but that the way in which literature and policy has considered science-society interaction is not fairly constructed to capture the potentialities and the usefulness of SSHA area. This study addresses the imbalance discussion about the widespread belief that SSHA is less useful than STEM and questions it. There is a policy failure that has put the SSHA on the backburner in the debate of the valuable knowledge production, hence, a review of this assumption should be done taken into account the SSH characteristics underlined in the present paper in order to restore a balance between the SSHA and STEM contributions to society, even if these contributions are done through different ways or to different agents.

The study has some limitations which point to areas for future research. First, we are using an existing database that has not been elaborated ad hoc to the needs of our research. Thus, some of the variables could be considered as a proxy to test our hypotheses. However, although the data were gathered with another purpose, empirical results have mostly supported the predictions build on the theoretical discussion. Then, we are aware that for this first explorative study, we have considered SSH and STEM areas as a whole, without making differences within areas. Future research should also consider disaggregating the area of knowledge into their disciplines and compare them.

Despite these limitations, we believe that the results of this study are satisfactory as they represent a first attempt to gain a better understanding of the existing differences between SSHA and STEM in the science system and the socio-economic environment; and to highlight the factors underlying the place given to each area of knowledge in these contexts. Moreover, this study could guide for future researches aimed to develop the needed measures that place SSHA area at the same level than STEM.

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BIBLIOGRAPHY

- Abreu, M., Grinevich, V., Hughes, A. and Kitson, M. (2009). Knowledge exchange between academics and the business, public and third sectors. Cambridge: UK Innovation Research Center.
- AHRC (2009). Leading the World. The economic impact of UK arts and humanities research. Arts and Humanities Research Council.
- Bakhshi, H., Schneider, P. and Walker, C. (2008). Arts and humanities research and innovation. London: Arts and Humanities Research Council and NESTA.
- Bakhshi, H., Schneider, P. and Walker, C. (2009). "Arts and Humanities Research in the Innovation System: The UK Example". *Cultural Science* **2**: 1-23.
- Bate, J. (2011) *The public value of the humanities*, London: Bloomsbury.
- Benneworth, P. and Jongbloed, B. W. (2010). "Who matters to universities? A stakeholder perspective on humanities, arts and social sciences valorization", *Higher Education* **59**: 567-588.
- Bigelow, J. (1998). Valuing humanities research, in Australia Academy of the Humanities (Ed.) *Knowing ourselves and others: the humanities in Australia into the 21st century* (Vol. 3) Reflective Essays. Canberra: Commonwealth of Australia, 37-58.
- British Academy (2004). That Full Complement of Riches': The Contributions of the Arts, Humanities and Social Sciences to the Nation's Wealth. London: British Academy.
- British Academy (2008). Punching our weight: the humanities and social sciences in public policy making. London: British Academy.
- Bullen, E., Robb, S. and Kenway, J. (2004). "'Creative destruction': knowledge economy policy and the future of the arts and humanities in the academy", *Journal of Education Policy* **19**: 3-22.
- Cassidy, E. and Ang, I. (2006). "Humanities-industry partnerships and the 'Knowledge society': The Australian experience", *Minerva* **44**: 47-63.
- Castro-Martínez, E., Molas-Gallart, J. and Olmos-Peñuela, J. (2011). Knowledge transfer in the Social Sciences and the Humanities: informal links in a Public Research Organization. *Atlanta Conference on Science and Innovation Policy*. Atlanta (United States). 15-17 September 2011.
- Cohen, W. M., Nelson, R. R. and Walsh, J. P. (2002). "Links and impacts: the influence of public research on industrial R&D", *Management Science* **48**: 1-23.
- Crossick, G. (2009). So who now believes in the transfer of widgets? *Knowledge Future Conference*. Goldsmiths.
- CSIC(2011). Annual report 2010. Madrid: Consejo Superior de Investigaciones Científicas (CSIC).
- D'Este, P. and Patel, P. (2007). "University-industry linkages in the UK: what are the factors underlying the variety of interactions with industry?", *Research Policy* **36**: 1295-1313.
- Dassen, A. and Benneworth, P. (2011). Arts & Humanities research between objective values and normative valuations? *Paper presented to "What is the value for arts and humanities research". Roundtable, part of the Consortium of Higher Education Research (CHER) Annual Conference, "What are the prospects for higher education in the 21st century? Ideas, research and policy".* Reykjavik, Iceland.
- Edgar, A. and Pattison, S. (2006). "Need humanities be so useless? Justifying the place and role of humanities as a critical resource for performance and practice", *Medical humanities* **32**: 92-98.

- European-Commission (2010). Unlocking the potential of cultural and creative industries. Brussels: Green Paper, COM 183.
- Gascoigne, T. and Metcalfe, J. (2005). Commercialisation of research activities in the humanities, arts and social sciences in Australia. Australia: CHASS Occasional Papers Nº1, Council for Humanities, Arts and Social Sciences (CHASS).
- Geuna, A. and Muscio, A. (2009). "The governance of university knowledge transfer: a critical review of the literature", *Minerva* **47**: 93-114.
- Hartley, J. and Cunningham, S. (2001). Creative Industries: from Blue Poles to fat pipes. In Gilles, M. (Ed.) *Paper presented at the National Humanities and Social Sciences Summit July 2001*. Canberra, Commonwealth of Australia.
- Howard, D. (2011). Architectural History in Academia and the Wider Community. In Jonathan Bate (ed.) *The Public Value of the Humanities*, London: Bloomsbury, 76-86.
- Hughes, A., Kitson, M., Probert, J., Bullock, A. and Milner, I. (2011). Hidden Connections: Knowledge exchange between the arts and humanities and the private, public and third sectors. Arts and Humanities Research Council (AHRC) and Center for Business Research, Cambridge.
- Jaaniste, L. (2009). Placing the creative sector within innovation: The full gamut. *Innovation: management, policy & practice*, **11**, 215-229.
- Olmos-Peñuela, J. and Benneworth, P. (2012). Are STEM from Mars and SSH from Venus? A comparison of research and transfer activities in the hard and soft disciplines. Working paper.
- O'Neill, O. (2011). *Foreword*. In Jonathan Bate (ed.) *The Public Value of the Humanities*, London: Bloomsbury, v-viii.
- OECD (2002). Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development. Paris: OECD.
- OECD (2005). Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data, 3rd Edition. Paris: OECD.
- Perkmann, M. and Walsh, K. (2007). "University-industry relationships and open innovation: towards a research agenda", *International Journal of Management Reviews* **9**: 259-280.
- Pilegaard, M., Moroz, P. W. and Neergaard, H. (2010). "An auto-ethnographic perspective on academic entrepreneurship: Implications for research in the social sciences and humanities", *Academy of Management Perspectives* **24**: 46-61.
- Schartinger, D., Rammer, C., Fischer, M. M. and Frohlich, J. (2002). "Knowledge interactions between universities and industry in Austria: sectoral patterns and determinants", *Research Policy* **31**: 303-328.
- Stannage, T. and Gare, D. (2001). Partnerships and collaborations: The importance to humanities, social sciences and creative arts. *Paper presented at the National Humanities and Social Sciences Summit July 2001*. Canberra: Commonwealth of Australia.
- Stokes, D. E. (1997). *Pasteur's Quadrant: basic science and technological innovation*, Washington, D.C.: The Brookings Institution.

ANNEX 1

Taxonomy of the stylized facts

Research and transfer practices	The lack of visibility of SSHA contribution
	Higher regional orientation of the SSHA (geographical scope)
	SSHA research for small audiences (scalability scope)
	Higher purpose of SSHA
Research identity	Misperception of the importance of business in receiving research
	Divergence in the field and no simple message
Users	SSHA research users are mostly non-economic agents
	Invisibility of research to the user in the consumption process (lack of traceability)

ANNEX 2

Summary of the hypotheses

Research and transfer practices	H1. SSH researchers are more concerned with the pursuit of fundamental understanding whereas STEM researchers are more focused on considerations of use.
	H2. SSH researchers use a higher proportion of informal pathways and a lower proportion of formal pathways to interact with non-academic actors compared to STEM researchers.
	H3: The frequency of involvement SSH with national users related to international users is higher for SSH researchers than for STEM researchers.
	H4. STEM researchers feel more that there are few user organisations interested in their research than STEM researchers.
	H5 SSH researchers spend more time in diffusion activities than STEM researchers.
Research identity	H6. SSH researchers collaborate less with firms than STEM researchers.
	H7. SSH researchers have less interest in checking the validity and applicability of their research than STEM researchers.
Users	H8. The frequency of collaborations with non-economic agents relative to private sector is higher for SSH researchers than for STEM researchers.
	H9. SSH researchers use less pathways that reach end users than STEM researchers and more pathways that reach intermediate users.